PIER Energy-Related Environmental Research
Environmental Impacts of Energy Generation, Distribution and Use

Evaluating Past and Improving Present and Future Measurements of Black Carbon Particles in the Atmosphere

Contract #: 500-02-004-WA MR-043-01
Contractor: Lawrence Berkeley National Laboratory
Contract Amount: $75,000
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The Issue

In California, air pollution levels for fine particulate matter persistently exceed air quality standards in 12 counties reaching from the central to the southern part of the state. Fine particles in the air are a public health concern because they are small enough to be inhaled and deposited directly in the lungs, where they can cause asthma and other health problems. One common type of fine particulate, the soot produced from the combustion of diesel fuel, is considered a toxic air contaminant in California.[1] In addition to posing a health risk, diesel soot contributes to climate change. The black core of the soot, known as black carbon (BC), strongly absorbs sunlight and causes about as much global warming as the greenhouse gas methane.[2] In addition, sunlight absorption by BC is believed to influence regional climate by altering the hydrologic cycle, reducing cloudiness, and melting snow and ice.[3,4,5]

Although emissions from power plants represent a small source of BC soot in California, the trend toward distributed energy resources in California will likely continue. Distributed energy resource equipment includes microturbines, conventional combustion turbine generators, and reciprocating engines, all of which may run on diesel fuel. Also, a portion of the backup utility generators used during power outages in California are diesel fueled.

Concern about the public health and climate effects of BC soot has prompted scientists and regulatory agencies to develop emission inventories, determine emission trends, and better

[1] California Air Resources Board (CARB). "Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles." October 2000. Available online at http://www.arb.ca.gov/diesel/documents/rrpapp.htm.

[2] Jacobson, M. Z. Strong Radiative Heating due to the Mixing State of Black Carbon in Atmospheric Aerosols. *Nature* 409: 695–697. 2001.

[3] Ackerman, A. S., O. B. Toon, D. E. Stevens, A. J. Heymsfield, V. Ramanathan, and E. J. Welton. "Reduction of tropical cloudiness by soot." *Science* 288: 1042–1047. 2000.

[4] Menon, S., J. Hansen, L. Nazarenko, and Y. F. Luo. Climate effects of black carbon aerosols in China and India. *Science* 297: 2250–2253. 2002.

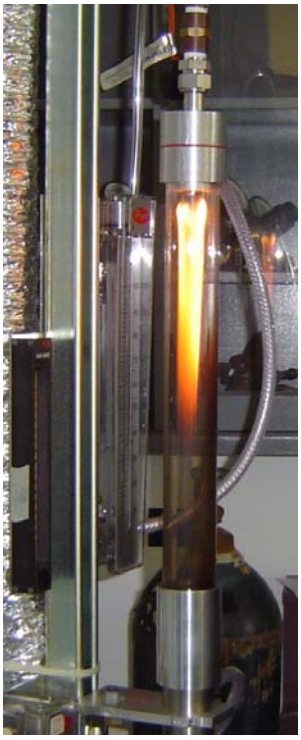
[5] Hansen, J., and L. Nazarenko. "Soot climate forcing via snow and ice albedos." *Proc. Natl. Acad. Sci.* 101: 423–428. 2004.

understand the atmospheric chemistry and physics of BC. Many of these efforts require a method for measuring BC concentrations accurately. It is widely recognized, however, that measurements of BC are highly uncertain. Moreover, BC measurements have been made only recently, so any retrospective analysis of BC air pollution must rely on proxy data that can be related to modern BC measurements.

Project Description

This project aims to improve the certainty of BC measurements by evaluating the performance of the aethalometer, which is one of the most widely used instruments for measuring BC concentrations. The aethalometer filters particles from the air and estimates the amount of BC in the particles by measuring the amount of light absorbed by the filtered particles. This instrument is similar to another which had been used extensively in California to quantify particulate matter air pollution in terms of coefficient of haze (COH).

A growing body of scientific evidence, including preliminary work by the research team, suggests that the calibration of the aethalometer is overly simplified and results in inaccurate measurements of BC concentration. This project will evaluate aethalometer accuracy using a specialized combustion apparatus developed at Lawrence Berkeley National Laboratory. The apparatus is an inverted diffusion flame that was designed to generate controllable amounts of BC particles. As in a diesel engine, BC forms in the fuel-rich region of the flame. Laboratory experiments will subject the aethalometer and COH instruments to known amounts of BC and to BC mixed with other constituents common to atmospheric particles, such as organic compounds and sulfates. The accuracy of aethalometer measurements will be assessed and, as needed, a new calibration will be developed.



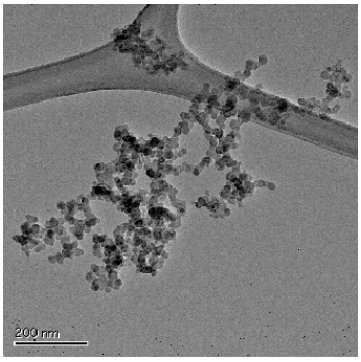


Photo courtesy Randy VanderWal, NASA Glen Research Center

An image of soot, obtained using High Resolution Transmission Electron Microscopy, that reveals its highly agglomerated structure. The soot was generated at Lawrence Berkeley National Laboratory using the inverted diffusion flame shown here.

In addition to improving BC measurements made with the aethalometer, this project also intends to relate modern measurements of BC with historical measurements of COH and to use the California record of COH to estimate the past history of BC in the atmosphere. Laboratory experiments will provide a comparison of BC and COH measurements. Archived records of BC and COH concentrations measured at air monitoring facilities in California will be accessed for additional comparisons. The lab and field data will be analyzed to determine the relationship between contemporary BC and historical COH measurements. Statewide BC trends will be estimated based on COH measurements made at a large number of sites in California from the mid-1960s to the present.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Providing safe energy.** Improving the accuracy of measured BC concentrations will aid epidemiologists and climate change scientists in understanding how BC soot affects public health and the environment.

- **Providing environmentally sound energy.** In addition to the direct effects of BC on climate and air quality, light extinction by BC impacts the chemistry that leads to the formation of other air pollutants, including ground-level ozone. Ozone is both a pervasive urban air pollutant and a potent greenhouse gas. Moreover, temporally and spatially resolved BC concentrations in California will be useful for examining how air quality and aerosol climate forcing have been influenced by past changes in energy technology, fuel consumption, and emission control strategies in California. Such information will provide regulators and other decision makers with a better foundation for planning the state's future energy supply.

Final Report

PIER-EA staff intend to post the final report on the Energy Commission website in fall 2007 and will list the website link here.

Contact

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